

# Multiple Spacecraft Classification for Formation Flying Definition

Finn Ankersen

`finn.ankersen@esa.int`

European Space Agency



# What do we mean ?

- What is Formation Flying ?
- Is it all clear ?
- Do we all mean the same when we use the term and understand each other right away ?



# What do we mean ?

# NO



# Needs ?

- Will it be useful that we do kind of understand the same thing ?
- Do we need some sort of standard ?



# Needs ?

# YES

# Example 1

- First automatic RendezVous and Docking was between Cosmos 186 and 188
- Well, someone has recently decided to consider this as Formation Flying in a presentation!
- Let us not change the history and the terms associated to it since 4 decades.

## Example 2

- Automatic RVD between 2 spacecraft, typically to the ISS.
- RGPS is used for navigation and actually forms an instrument between the 2 spacecraft and the GPS constellation.
- That scenario should still be considered as RVD.
- The same is the case for servicing and repair missions of spacecraft, e.g the newly considered robotic repair of Hubble.
- That would be RVD.

## Example 3

- The GPS system with its 24 satellites and some receiver will form an instrument.
- That will not make it become formation flying
- Should be considered as a constellation as done so far.



## Example 4

- The Cluster mission is 4 spacecraft, spinning, which is placed far apart in the outer Earth magneto-sphere.
- It is a scientific instrument to measure the magneto-spheric tail and particles in it.
- There is no control of the spacecraft relative nor absolute position state vectors.
- The mission is considered as a constellation.

## Example 5

- The LISA 3 spacecraft mission to measure gravitational waves.
- It is a very high precision scientific instrument based on drag free technology of proof masses.
- The inter spacecraft distances are measured by laser interferometry to a very high precision.
- The spacecraft are on an Earth trailing orbit 5 000 000 km apart in a triangle.
- The relative position vector is not controlled and they are free drifting over the mission time.
- The mission is considered as a spacecraft constellation.

## Example 6

- The XEUS X-ray observatory consists of 2 spacecraft flying 50 m apart. Detector and lens.
- The relative state position vector must be controlled to better than 1 millimeter and relative attitude is controlled also.
- The mission is considered as a formation flying mission.



# RendezVous and Docking 1/2

- The mission consists of 2 spacecraft.
- The relative position and velocity between the 2 spacecraft are controlled and possibly at certain parts also the relative attitude.
- The spacecraft are moving on quasi-coplanar orbits.
- The spacecraft are in close proximity, which means typically below 30 km separation where the relative motion is in a linear domain closing in to distances of meters or even contact.
- There is no need to define to define a plane for inter spacecraft positions other than the orbital plane.



# RendezVous and Docking 2/2

- The GNC requirements are typically medium to high or very high for some scientific mission.
- Rescue and repair missions with both cooperative and non cooperative targets fall into this category.

# Constellations

- The mission consists of 2 or more spacecraft.
- The relative position and velocity between the spacecraft are not controlled, except to orbital station keeping points predefined at mission design.
- The spacecraft are typically distributed on the same orbit (e.g. tandem flights) but can very well be on different orbits.
- There is no close proximity between the spacecraft in terms of maneuvering and state vector coordination.
- There is no plane defined for the inter spacecraft positions other than the orbital planes.
- The GNC requirements are typically low to medium.



# Formation Flying 1/2

- The mission consists of 2 or more spacecraft.
- The spacecraft states are directly coupled coupled such that changing the state of one spacecraft affects the state of all other spacecraft. This includes possible state elements from optical delay lines etc.
- The relative position and velocity between the spacecraft are controlled and possibly at certain parts also the relative attitudes.
- The spacecraft are moving on quasi coplanar orbits or perhaps Lagrange points.



# Formation Flying 2/2

- The spacecraft are in close proximity, which means typically below a few km separation where the relative motion is in a linear domain. (though some proposals have rather large distances)
- A plane is defined for the inter spacecraft positions with an arbitrary orientation in space and with respect to a possible local orbital frame. Spacecraft do not all have to be in that plane in their nominal position.
- The GNC requirements are typically high to very high.





# Your Opinion!!

- Your feedback is needed and welcome for refining these definitions.
- Please send your constructive and justified comments to:
- [Finn.Ankersen@esa.int](mailto:Finn.Ankersen@esa.int)